GeoEye-1 Geolocation Assessment and Reporting Update

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GeoEye®

GE-1 Geolocation Update

- The geolocation accuracy performance assessment for GeoEye-1 system during 2010 was better than 4 meters for mono CE90 and stereo CE90/LE90.
- Average relative geolocation CE90 performance of better than 1 meter for points separated by 50 km.
- The geometric calibration of GE-1 was maintained with 4 camera interlock updates during 2010.
- GE-1 Community Sensor Model (CSM) was delivered in 2010.

GE-1 Geolocation Accuracy Test Results

Period	Mono		Stereo		
	# images	CE90 (m)	# pairs	CE90 (m)	LE90 (m)
2009 Q2-Q4	530	3.6	222	3.4	3.2
2010	136	3.8	65	3.5	3.5
2011 Q1	15	3.3	6	3.3	3.8

- Based on rigorous (physical) model
- Direct positioning
  - No adjustment of imagery
- Typical collection geometry was up to 30 degrees off nadir angle and stereo convergence angle of 45 degrees

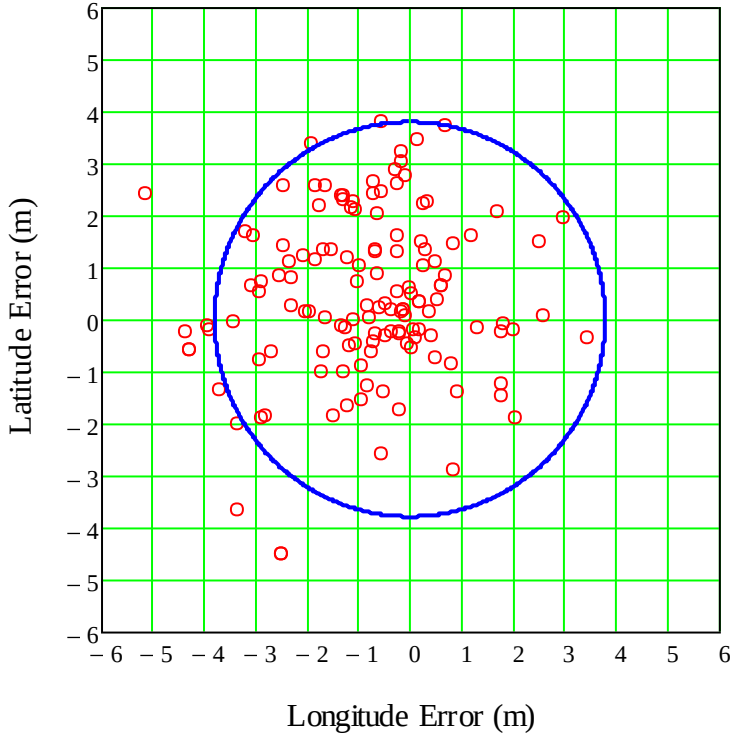
GE-1 Absolute Mono Geolocation Accuracy for 2010

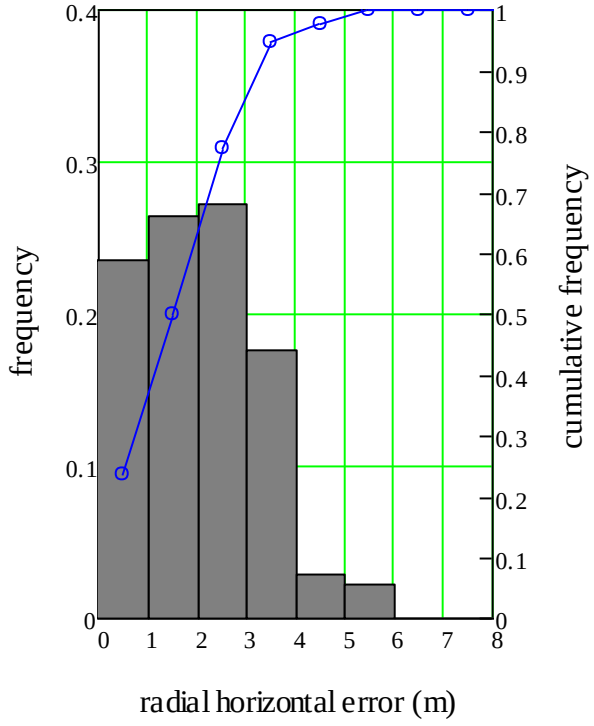
CE90 = 3.8 meters

n = 136

mean ($\Delta\phi$) = 0.4 m mean ($\Delta\lambda$) = –0.8 m

stdev ($\Delta\phi$) = 1.6 m stdev ($\Delta\lambda$) = 1.6 m





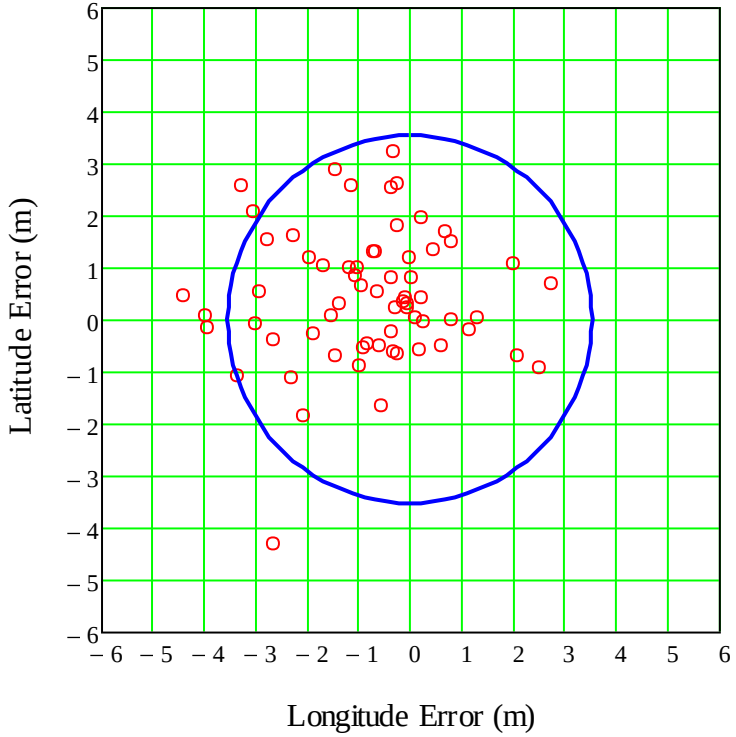
GE-1 Absolute Stereo Geolocation Accuracy for 2010

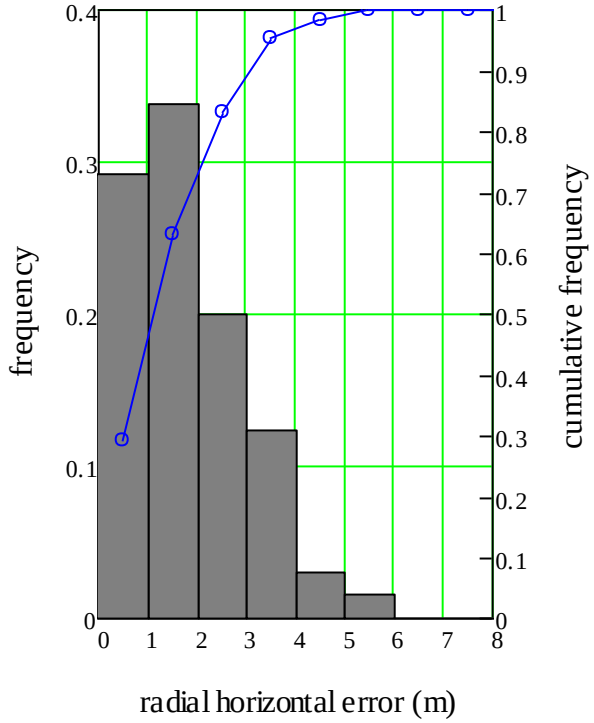
CE90 = 3.5 meters

n = 65

mean ($\Delta\phi$) = 0.4 m mean ($\Delta\lambda$) = –0.8 m

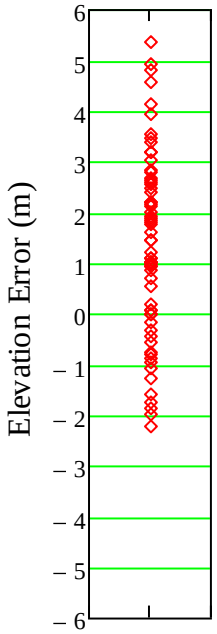
stdev ($\Delta\phi$) = 1.3 m stdev ($\Delta\lambda$) = 1.5 m





GE-1 Absolute Stereo Geolocation Accuracy for 2010

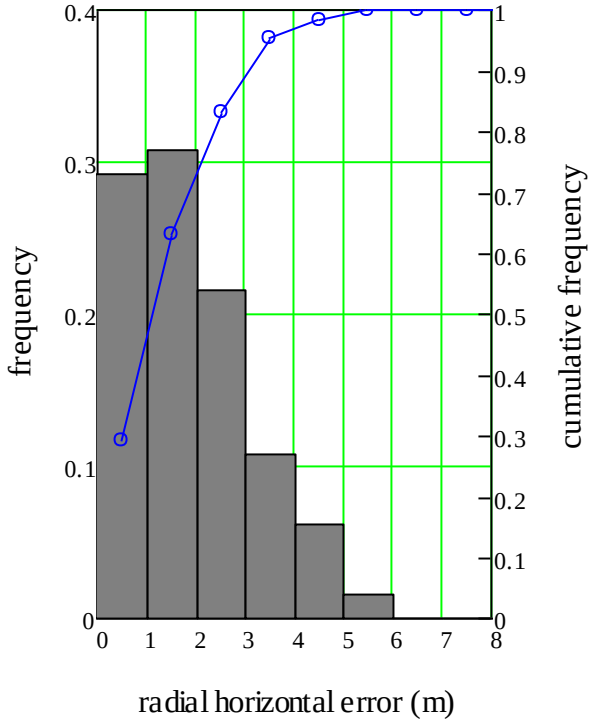
LE90 = 3.5 meters



n = 65

mean (Δh) = 1.4 m

stdev (Δh) = 1.8 m



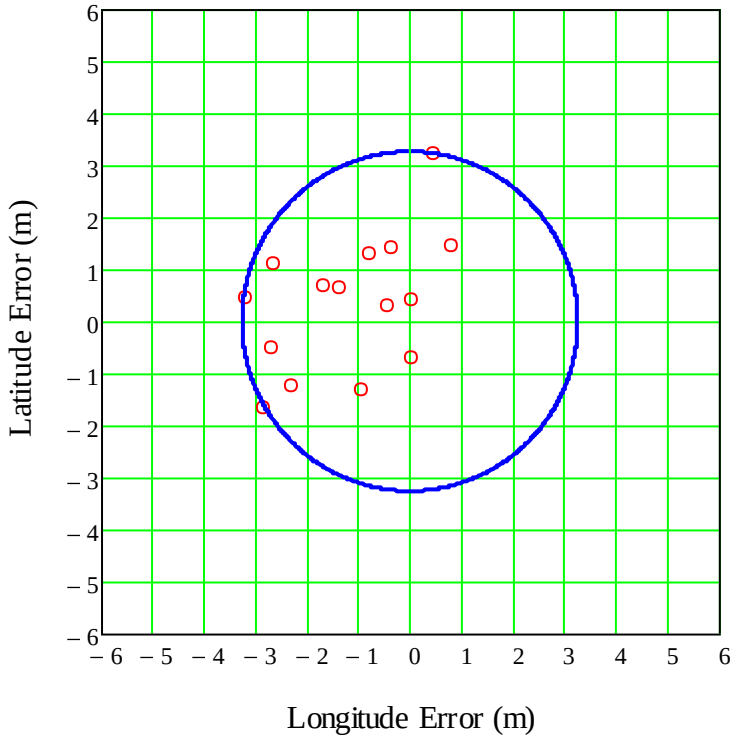
GE-1 Absolute Mono Geolocation Accuracy for Q1 2011

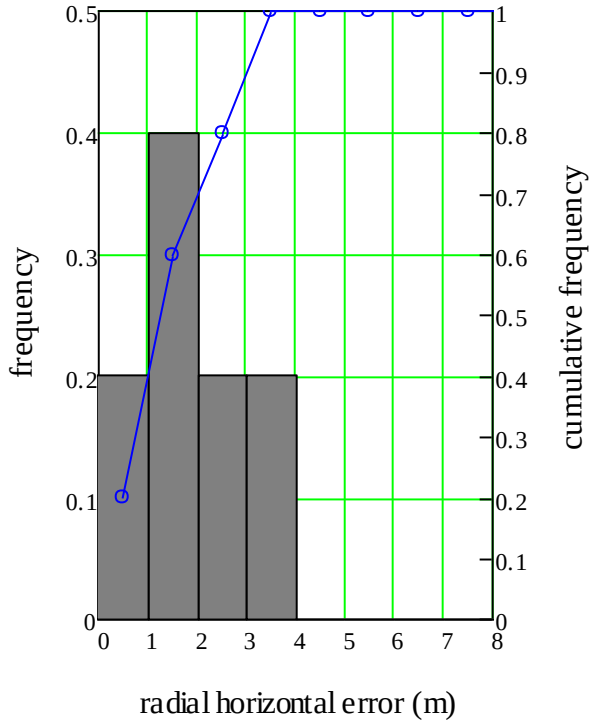
CE90 = 3.3 meters

$n = 15$

$\text{mean}(\Delta\phi) = 0.4\,\text{m}$ $\quad \text{mean}(\Delta\lambda) = -1.2\,\text{m}$

$\text{stdev}(\Delta\phi) = 1.3\,\text{m}$ $\quad \text{stdev}(\Delta\lambda) = 1.3\,\text{m}$





GE-1 Absolute Stereo Geolocation Accuracy for Q1 2011

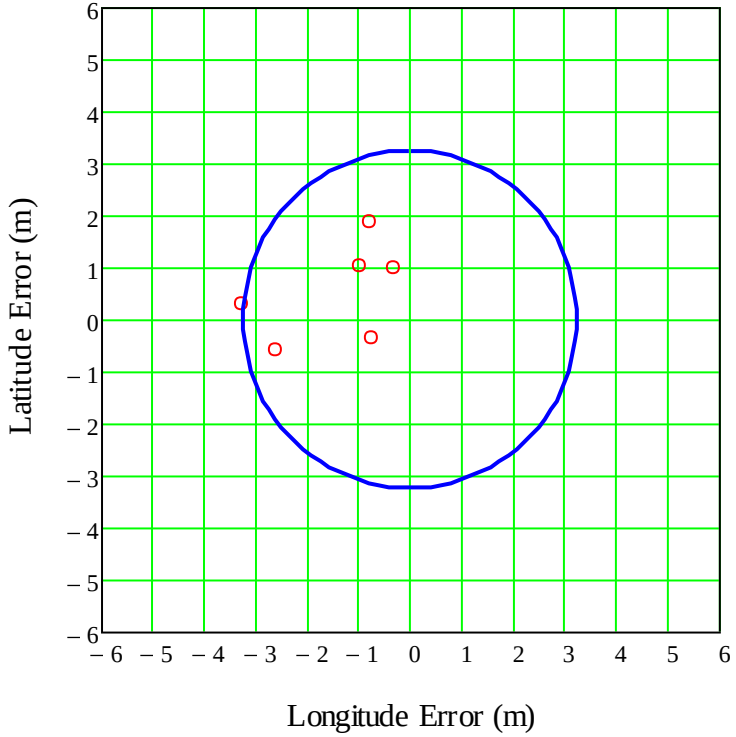
n = 6

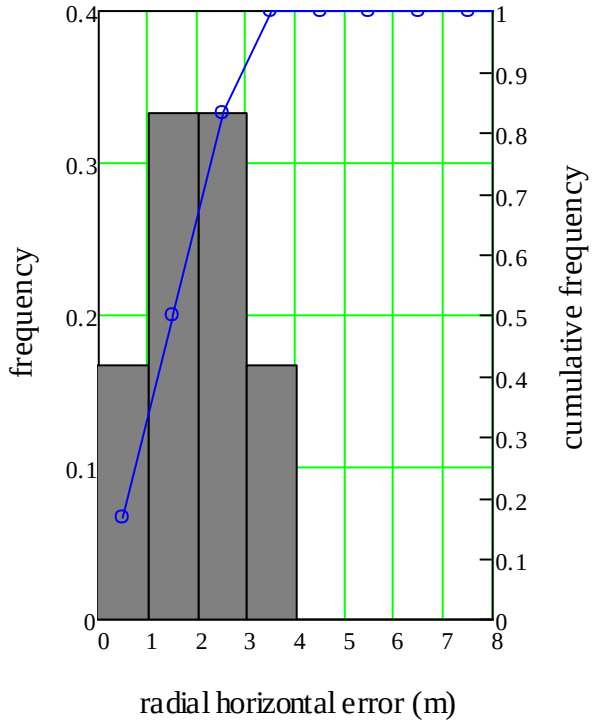
max radial error = 3.3 meters

mean(Δϕ) = 0.6 m mean(Δλ) = −1.5 m

Max error reported due to small sample size

stdev(Δϕ) = 0.8 m stdev(Δλ) = 1.1 m





GE-1 Absolute Stereo Geolocation Accuracy for Q1 2011

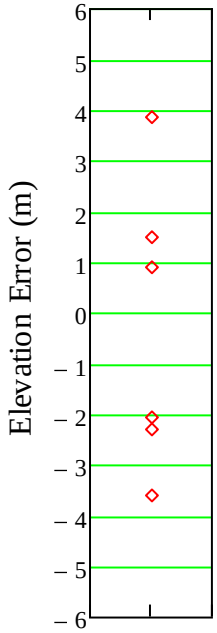
max elev error = 3.8 meters

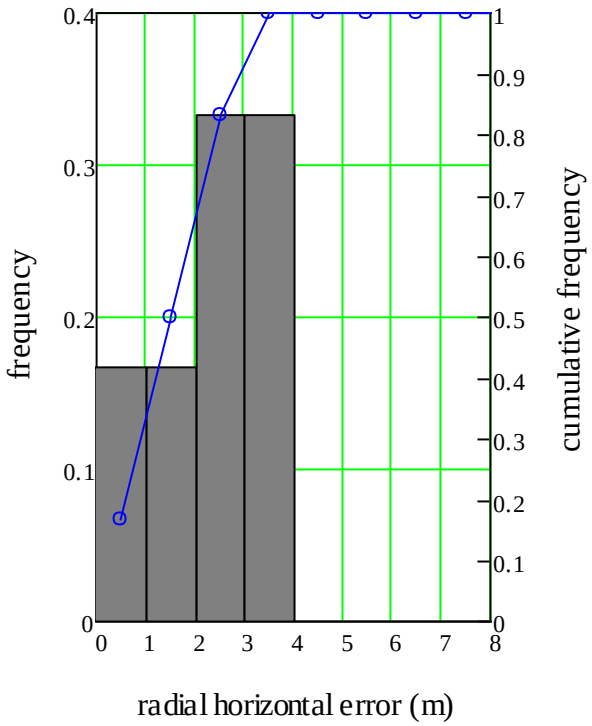
Max error reported due to small sample size

$n = 6$

$\text{mean}(\Delta h) = -0.3\text{m}$

$\text{stdev}(\Delta h) = 2.6\text{m}$



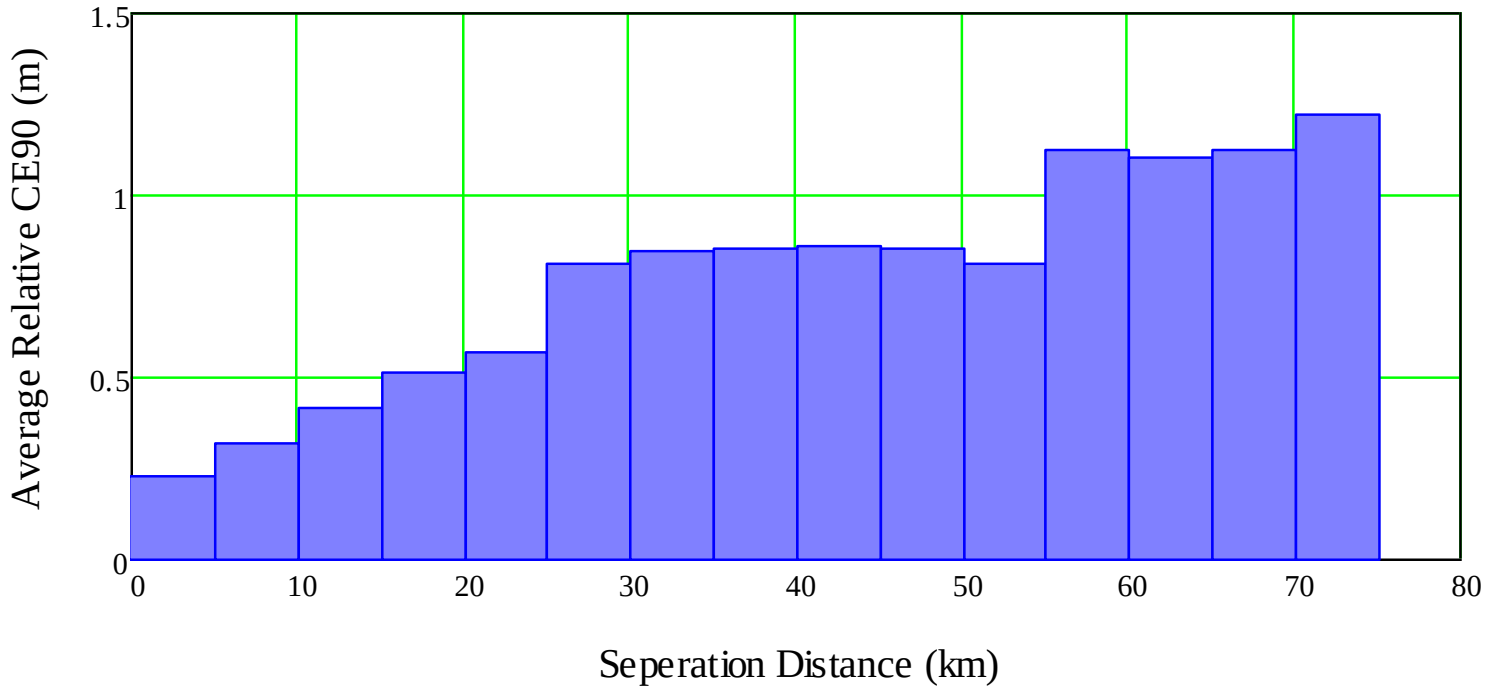


GE-1 Relative Geolocation Accuracy Test Results for 2010

100115_phoenix_1st	0.3	0.5	0.8	1.1	1.1	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.3	1.4
100115_phoenix_2nd	0.2	0.2	0.4	0.6	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.0	1.0	1.0
100121_perth_1st	0.3	0.3	0.5	0.5	0.5										
100121_perth_2nd	0.3	0.3	0.4	0.4	0.5										
100129_perth_1st	0.3	0.3	0.4	0.4	0.4										
100129_perth_2nd	0.2	0.2	0.3	0.4	0.4										
100131_perth_1st	0.3	0.3	0.5	0.6	0.7	0.9									
100201_perth_1st	0.2	0.2	0.2	0.4	0.3										
100209_perth_1st	0.3	0.3	0.3	0.3	0.3										
100209_perth_2nd	0.2	0.3	0.4	0.4	0.4										
100212_perth_1st	0.2	0.3	0.3	0.3	0.3										
100212_perth_2nd	0.2	0.2	0.3	0.3	0.3										
100903_perth_1st	0.2	0.2	0.3	0.3	0.3										
100903_perth_2nd	0.3	0.6	0.9	1.1	1.5										
100906_perth_1st	0.2	0.3	0.3	0.4	0.4										
100906_perth_2nd	0.3	0.5	0.7	0.9	1.0										
100928_phoenix_1st	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6				
101008_phoenix_1st	0.1	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.6	0.5				
101130_perth_1st	0.3	0.3	0.3	0.3	0.3										
101130_perth_2nd	0.3	0.3	0.3	0.3	0.3										
101210_phoenix_1st	0.2	0.3	0.4	0.6	0.7	0.8	0.8	0.8	0.8	0.8	0.8				
101210_phoenix_2nd	0.2	0.4	0.6	0.9	1.1	1.2	1.2	1.2	1.1	1.1					
Mean Relative CE90 (m)	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.8**	**0.8**	**0.9**	**0.9**	**0.9**	**0.8**	**1.1**	**1.1**	**1.1**	**1.2**
Separation Distance	**0km**					**25km**					**50km**				**75km**

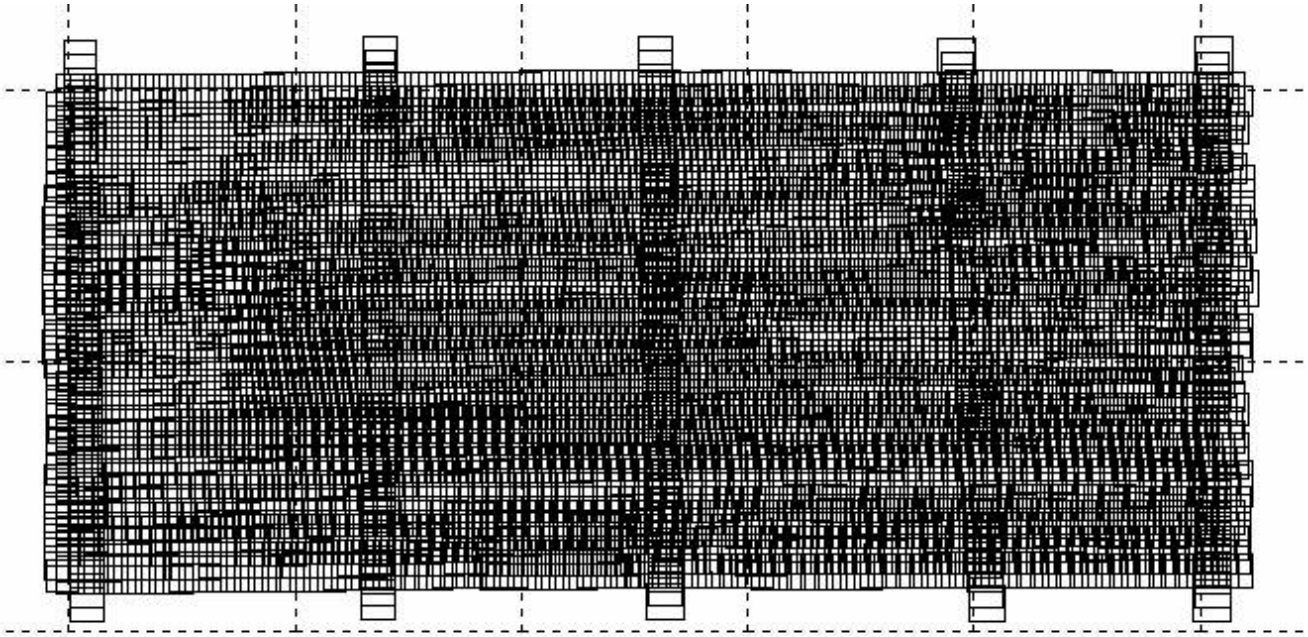
CE90 = 1 meter is 0.15 arcsec (1σ) per axis at GE-1 orbit

GE-1 Relative Geolocation Accuracy Histogram for 2010



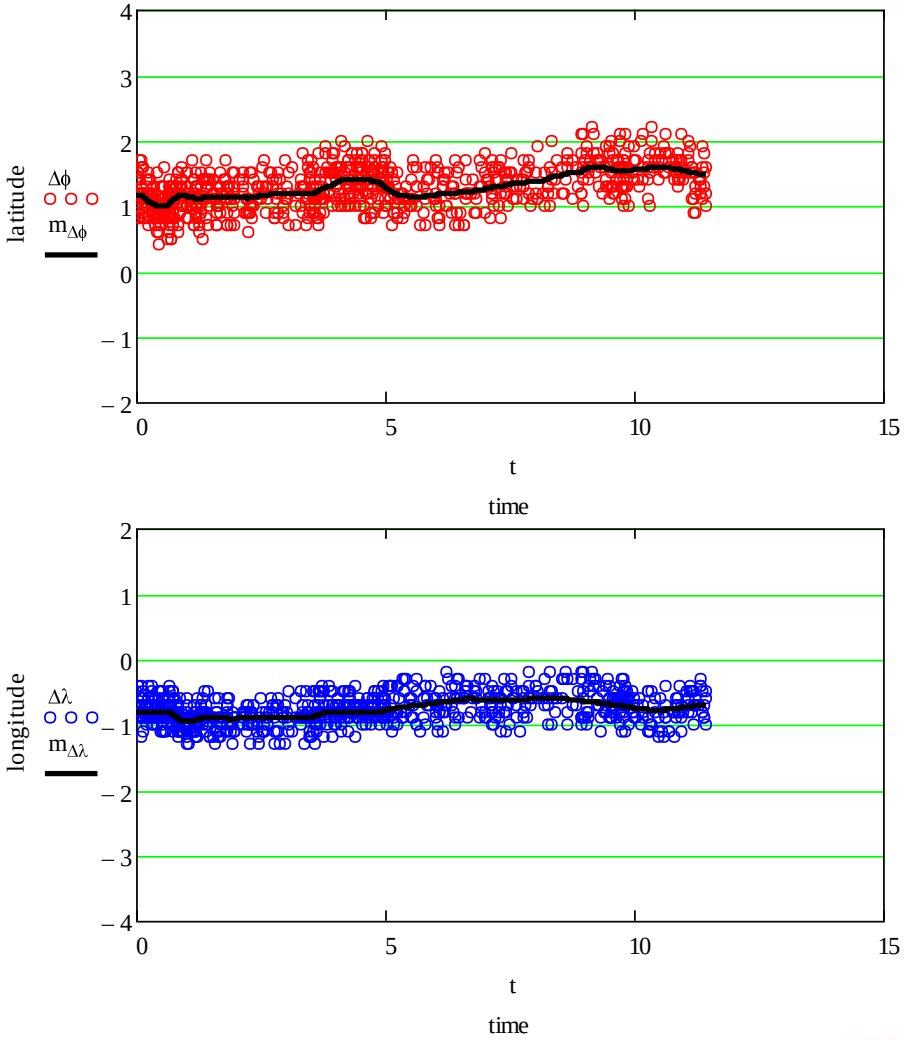
Phoenix Geometric Calibration Range

- Aerial photos with 60% endlap and 60% sidelap
- Geodetic control survey
- Block triangulation and control point generation
- Image correlation is used to match aerial image points to satellite



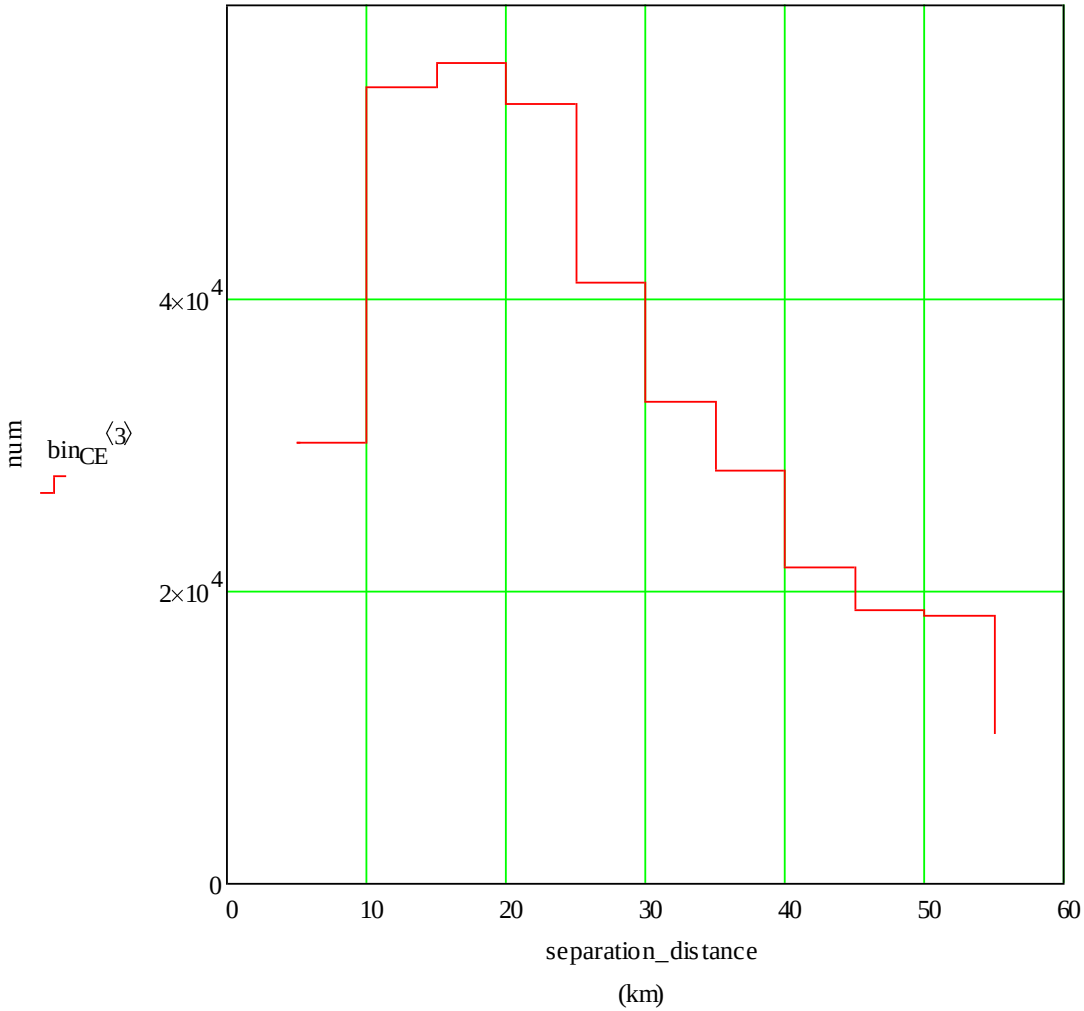
Geolocation Error Times Series

- The horizontal error for each satellite image point is computed
- A median moving boxcar filter is used to determine the geolocation error for a given time (image line)
  - This reduces the matching error.
- Time series of the geolocation error are useful for visualization
  - Shown here as latitude error and longitude error times series



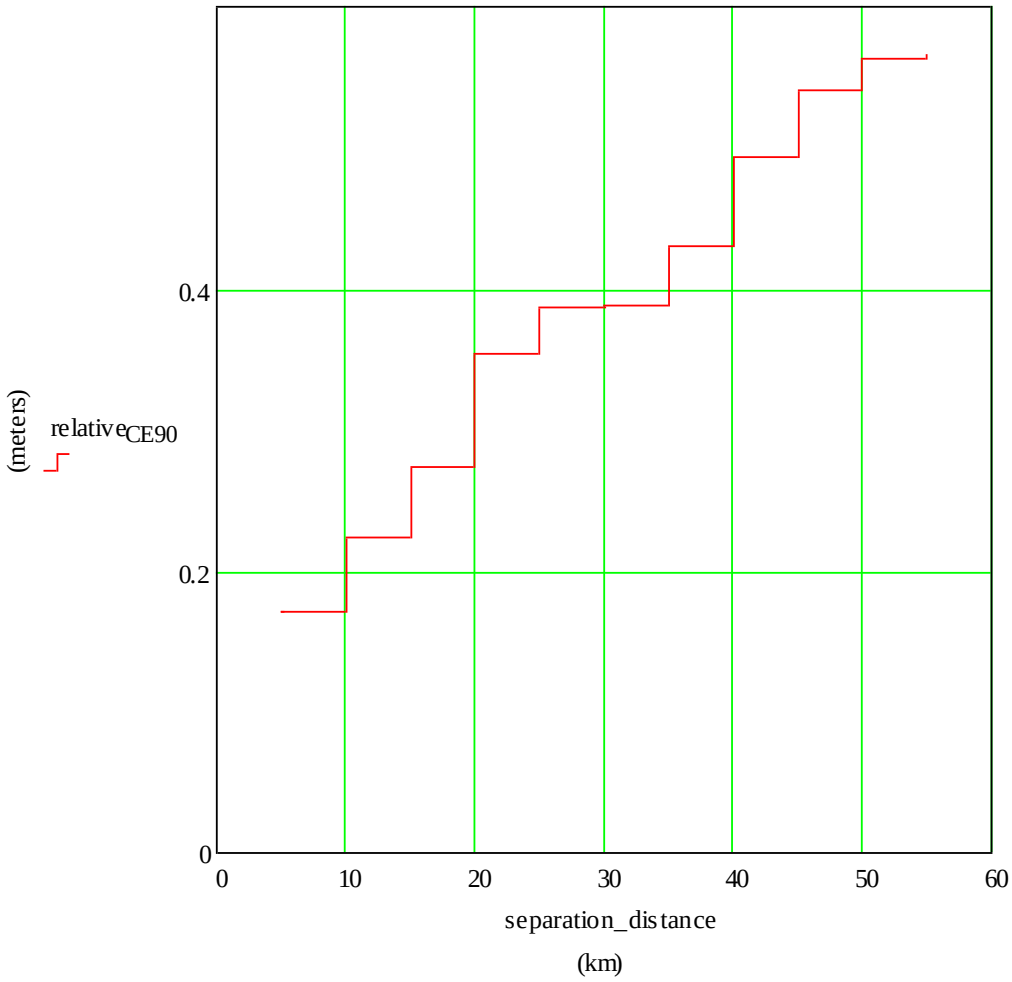
Point Pairs and Distance Bins

- For every point pair in the satellite image
  - Compute the distance for the point pair
  - Compute the relative radial geolocation error for the point pair
  - Add the relative geolocation error to the appropriate distance bin
- Shown here is the number of point pairs in a given distance bin



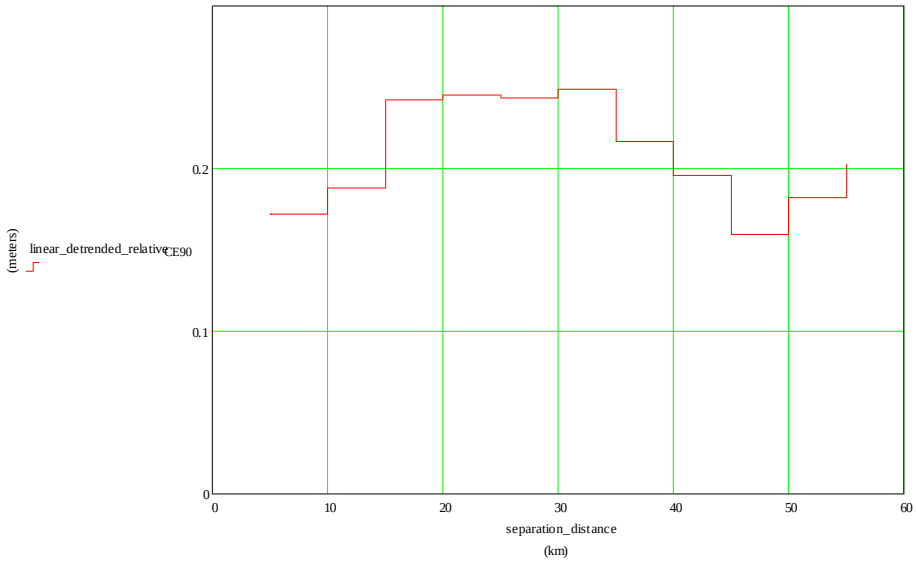
Relative Geolocation Error by Point Pair Separation Distance

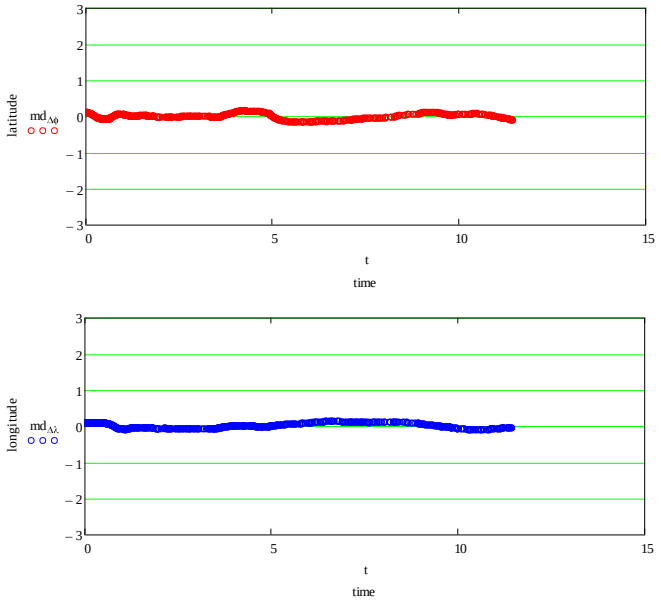
- For each distance bin
  - Sort each distance to establish the rank order for the relative radial distance
  - Determine the 90% of the rank order for the relative CE90
- Shown are the CE90 plotted against the separation distance bin



Removing Linear Trend from Relative Geolocation Error

- Some images contain linear trends. Linear trends may be estimated in block triangulation with other images.
- Removing the linear trend in the previous example shows the residual relative geolocation error. Shown below.
- In this example, the observed residual relative error is 0.3 pixel (1σ each axis)





GE-1 Geometric Calibration Update

- The GE-1 camera interlock angle calibration was updated 4 times during 2010: Feb, May, Aug and Nov

- The GE-1 Field Angle Map (FAM) did not require a calibration table update during 2010.
  - The imagery collected for relative geolocation accuracy assessment is also used to check the FAM

GE-1 Community Sensor Model

- *"The Community Sensor Model (CSM) Program will provide Government and Industry with the capability to create and maintain a standard program for developing, testing, and evaluating a collection of current and future sensor models. The models support Sensor Exploitation Tools (SETs) and other application tools that require a precise understanding of the image (data) and ground coordinate relationships. The CSMs are dynamically linked (or loaded) libraries that do not require re-compilation of the SET. Models may be added or removed from the SET without impact on the SET or other models. This capability will be used to accurately map a pixel (e.g., target location) on an image to a geo-referenced coordinate and provide rigorous error estimates."*

  - Community Senor Model Technical Requirements Document Introduction

- The GE-1 Community Sensor Model plug-in that supports photogrammetric functions such as:
  - Ingesting GE-1 metadata and ancillary data
  - Image to ground and ground to image projections
  - Numerical evaluations of partial derivatives with respect to image and sensor parameters
  - Error propagation through projection model
- Executable was built for: Red Hat Linux, Windows XP, Solaris 10
- The GE-1 CSM plug-in was delivered in July 2010 to NGA
- A GE-2 CSM is planned

Summary

- The GE-1 system continues produce very good geolocation accuracy performance
- The GE-1 system performance was maintained with periodic geometric calibration updates
- GE-1 Community Sensor Model plug-in has been built and tested